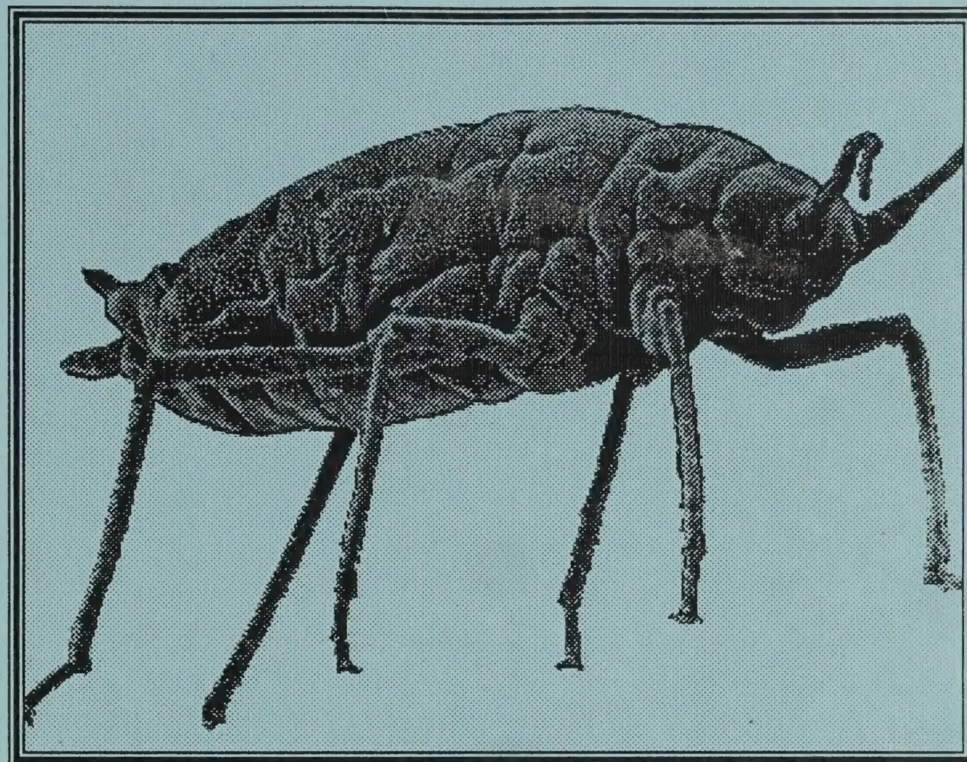
RWA



THE RUSSIAN WHEAT APHID

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Second Annual Report
November 1989

Compiled by Robert L. Burton, ARS Technical Coordinator
Plant Science Research Laboratory
Stillwater, Oklahoma

Agricultural Research Service
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Three and a Half Years Later

Preface to the Second Annual Report

By R. L. Burton, ARS Technical Coordinator,
Russian Wheat Aphid Programs

Three and a half years following the introduction of the Russian wheat aphid (RWA), *Diuraphis noxia* (Mordvilko) into the United States, Nevada and North Dakota have been added to its distribution list. The RWA is now found in the entire block of states that lie along and west of the 98th meridian. This block includes 17 states (see map, page 2) as well as three Canadian provinces. Two-thirds of the wheat planted in the United States, approximately 40 to 50 million acres, and much of the barley acreage, about 10 to 12 million acres, are located in this region and are threatened by the RWA. To date, damage by the RWA to grains in this area of the United States has exceeded $200 million. This is a significant amount, but it is still below the economic damage potential that exists with this pest. Except for a small portion of this range, economic damage has been sporadic and localized. Perhaps population densities and subsequent damage levels are regulated by local weather conditions. Therefore, the United States has been fortunate, thus far, in that only a small percentage of the total acreage has been damaged and/or has required chemical treatment. We can contrast this with the RWA situation in South Africa where approximately 40% of the wheat crop is treated annually for RWA (personal communication from Dr. F. du Toit to Dr. P. Morrison, 1986). The important question is whether or not we will be faced with future outbreaks of this magnitude.

The area infested by the RWA coincides with the arid/semiarid region of the Great Plains; the aphid appears to be more successful in regions with a mean annual rainfall of less than 20-25 inches (600 mm). This is not to say that rainfall is the only limiting factor for success of the RWA. In truth, the lack of movement eastward into higher rainfall areas has not been fully explained. The detection rate has been very low on the eastward edge of its range, indicating that populations are not increasing during favorable periods. Moreover, there have been no reports of heavy influxes of migratory forms toward the eastward edges. After its detection in 1986, the RWA's initial migratory movement was primarily in a northerly direction from the High Plains region of the Texas Panhandle to southeastern Wyoming; little eastward movement occurred at that time, indicating that migratory routes are probably dictated by prevailing wind direction, which may be one of the factors responsible for limited eastward movement.

Infestations of the RWA in winter wheat and winter barley in the United States appear to be developing another pattern. Serious fall infestations seem to be occuring only in the northern and northwestern portion of the pest's range, whereas spring infestations are the most damaging in the southern areas. An explanation for this might be that oversummering hosts, including grassy hosts and summer volunteer wheat, are available in the cooler northern areas but are sparse, at best, in the hot and dry areas of the southern Great Plains. In the colder northern areas, harsh winter temperatures decimate, or at least limit, winter populations to levels that cannot respond quickly enough in the spring to cause severe problems before the crop matures. Conversely, in the southern areas, fall populations are so reduced that they do not have time to build up to economic levels before cooler winter temperatures slow growth. Yet the winters are more favorable than in the North, permitting populations to gradually increase throughout the winter, until population growth

responds rapidly to increasing spring temperatures. Also, it is probable that cold fronts from the north move fall infestations southward, and strong southerly winds that occur in the spring move spring infestations northward. Conditions such as local weather patterns, protective snow cover, and cool moist summers in the southern areas may cause upredictable population responses. The intermediate areas, in the central region of the Great Plains, have the potential for both serious spring and fall infestations, dictated by annual weather conditions.

The research in the United States to counteract the RWA devastation to grain production is moving at a rapid pace. There are fundamental research programs that have answered basic questions concerning how the RWA is damaging plants during the feeding process. Feeding causes symptoms not unlike those caused by drought, that is, dramatically interferring with water maintenance and the osmoregulatory capacity of the plant. Plant physiological dysfunctions caused by feeding can be expressed as stunting, reduced root growth, delayed tillering, and other nonvisual symptoms. Other research indicates that the nutritional status, particularly nitrogen levels, plays an important part in the development of RWA damage symptoms. The fundamental work characterizing damage will aid in the development of better plant resistance screening techniques and will facilitate the management of crops under attack by RWA in the field.

A very encouraging aspect of RWA research has been the identification of plants that resist the feeding damage of this pest. Good resistance in wheat, barley, oats, rye, triticale, and forage grasses have been found by several RWA research locations. Most of these resistant lines come from areas where the RWA originates. These resistant sources are currently under intensive study, and many are in backcross programs in an effort to expedite the release of germplasm to public and private breeders. Damage to a crop under heavy RWA attack is so severe it seems remarkable that some plants are capable of revoking such an onslaught. However, very effective levels of resistance are being found that can eventually lead to an inexpensive, successful management strategy for growers. According to the breeders, the timeframe will be a minimum of six years for the development of an RWA-resistant, agronomically acceptable cultivar.

Biological control is another research area with encouraging results. Explorers searching for biocontrol agents have been very successful in finding potential candidates. As a matter of fact, biocontrol scientists have been overwhelmed by the number of parasite, predator, and disease species collected from RWA "countries of origin" and shipped to the United States. Now we must decide which of these species are the most effective, produce them in quantity, and then successfully establish them in the United States. Natural controls are essential if we are to manage the RWA effectively in the future. Some localized early establishments of beneficial insects are expected, but the effort required to introduce the many beneficial species into RWA populations across 17 states, which have extremely diverse climates and sporadic and/or seasonal RWA outbreaks, will likely take a period of several years.

Although the timeframe for alternatives to insecticides for RWA control is considerably longer than we would like, we have no other choice. Our strategy must be to explore as many alternatives as possible by expediting the research effort and the deployment of our research results. In the meantime, we can only hope that the RWA does not create the overwhelming problem for which it has the potential.

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Second Annual Report of the Agricultural Research Service
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Plant Science Research Laboratory
Stillwater, Oklahoma

Introduction

Following the introduction of the Russian wheat aphid (RWA), *Diuraphis noxia* (Mordvilko), in 1986, ARS research efforts on RWA consisted of a gradual redirection of the research programs at Stillwater, followed by redirections at other ARS locations as the problem became national in scope. Currently at least 80% of the cereal insect project at Stillwater is directed toward the RWA. Six ARS research scientists and one support scientist in the Wheat and Other Cereal Crops Research Unit spend a large portion of their efforts on RWA in six major areas. At the Northern Grain Insect Research Laboratory, Brookings, SD, three ARS research scientists are involved to a limited extent in host-aphid interaction, modeling, and predator research. The ARS European Parasite Laboratory, Behoust, France, has directed some of its foreign exploration to include natural enemies of the RWA. Collected materials, including parasites and predators, are sent to the ARS Beneficial Insects Introduction Laboratory, Newark, DE, and to the ARS Plant Protection Research Laboratory, Ithaca, NY, for quarantine and redistribution. Plant Protection Research is supporting insect pathology of RWA by providing expertise and colonies of pathogenic organisms. The ARS Biological Control of Insects Research Laboratory, Columbia, MO, is studying the genetic background of RWA parasites and predators. The ARS Biosystematics Laboratory, Beltsville, MD, has been involved in the aphid taxonomy and distribution. For more information, please see specific sections of the following report and the Personnel section on page 21.

The purpose of this report is to outline the ARS research activities and accomplishments related to the RWA for the preceding year. The report will be brief in many respects. Space does not allow for much detail, including extensive research plans for the future. Additional detail on the many aspects of RWA research is available on request.

RUSSIAN WHEAT APHID DISTRIBUTION

NOVEMBER 1989

RWA-Host Plant Interaction

Mission: To develop a fundamental understanding of the molecular nature of the physiological and biochemical basis of RWA damage to facilitate the development of resistant germplasm derived from both traditional breeding programs and genetic engineering techniques.

Stillwater, OK

Alterations of Growth Characteristics, Biomass Partitioning, and Host-Plant Physiology Caused by RWA Feeding

Using greenhouse-cultured 'TAM W-101' wheat seedlings, we evaluated several plant parameters as markers of RWA feeding damage. Results showed that RWA feeding caused significant reductions in both root and shoot biomass. Tiller development and leaf initiation were delayed, and significant differences in relative growth rates occurred within one week after aphid infestation. However, one week after RWA removal, growth rates had recovered to a level equal to the controls. This transitory response suggests that the RWA imposes an energy stress on the plant which is alleviated upon RWA removal. This is in sharp contrast to what has been found with toxigenic greenbug damage, where after aphid removal the growth rates increase, but at a decreasing rate relative to the controls (Burton, 1986). The most sensitive response variable measured was leaf area. Leaf area reductions were directly correlated with leaf rolling and stunting. Removal of the RWA ameliorated leaf stunting; however, convolutely rolled leaves never recovered, and new growth remained trapped. Rolled leaves were composed entirely of developing leaves of the plant and resulted from the prevention of unrolling. We observed no convolute rolling of expanded leaves. Following aphid removal, excision of the rolled growth stimulates rapid intercalary growth and the initiation of new leaves. Light microscopy revealed no apparent damage to either leaf primordia or the vascular bundles (i.e., no occlusions or collapse) in rolled leaves. However, epidermal bulliform cells of both expanded and nonexpanded leaves were collapsed. This condition is characteristic for water imbalances associated with severely reduced turgor.

Preliminary studies designed to evaluate plant physiological dysfunctions associated with the expression of RWA feeding damage have demonstrated the importance of the water and nutritional status of the host. Examination of the water relations of RWA-damaged wheat seedlings ('TAM W-101') revealed that there was a fourfold decrease of turgor in the rolled leaves of infested plants when compared with noninfested controls. Observed reductions in leaf size (stunting) and the prevention of leaf unrolling are consistent with these results in that turgor is the primary precursor of cell wall extensibility and leaf expansion. Because no other visible damage symptoms were observed at the time of sampling, it is hypothesized that the first impact of RWA feeding on the host involves the localized reduction of water maintenance in the infested leaves. Under controlled conditions, damage symptoms can be ameliorated (except for the rolled new growth) or exacerbated by manipulating the water and nutritional status of the plant. Physiological dysfunctions associated with the induced water stress in the infested leaves may play a primary role in the development of interveinal chlorosis. Evaluation of the water relations of RWA-infested resistant and susceptible triticale, oat, and wheat host plants showed that there is a significant correlation between turgor status and visible damage.

Comparison of Traditional Rating Systems with Plant Growth Characteristics for Evaluation of RWA Damage

The RWA feeds primarily on the new growth of its host. In the field, visible damage caused by feeding is typically manifested as chlorotic lesions, white streaking, purple discoloration, and tightly rolled leaves. However, screening for resistance in artificial environments has been difficult because each visible symptom can occur independently, and the sequence of damage events is further confounded by apparent environmental interactions. Consequently, traditional screening techniques, which are based on monogenic damage scenarios, have failed to give consistent results, both between greenhouses and in greenhouse and field studies. Studies focusing on the basic nature of RWA damage have been conducted to provide a better understanding of the plant response and to facilitate the development of a more precise damage evaluation system that will be useful in plant breeding programs.

Plant damage rating schemes have been widely used to evaluate host plant resistance. Rating scales typically range from 1 (no damage) to 9 (dead plant), with intermediate damage ratings corresponding to incremental levels of visible symptoms. Plant entries that had previously tested resistant or susceptible were used in a controlled test to compare rating system results with specific plant growth characteristics. Entries evaluated included oat (resistant), triticale (resistant and susceptible), and wheat (resistant and susceptible). In addition to the visible damage rating, plant stunting and leaf rolling ratings were made. Plant components quantitatively measured were tiller and leaf development, total leaf area, and total leaf length. Results of the leaf rolling and 1-to-9 damage ratings were consistent with those obtained from the initial screening tests in greenhouse flats. However, plant ratings for stunting indicated that both the oat and resistant wheat entries suffered significant reductions in shoot development. Analysis of plant growth components revealed substantial differences between infested and control plants for all entries except for the resistant triticale. Clearly, traditional damage rating schemes were adequate for identifying susceptible and resistant entries but performed poorly in measuring intermediate damage levels. Of the three rating systems used, plant stunting best predicted the quantitative damage responses.

Brookings, SD

Research on aphid-caused inhibition of root growth of seedling winter wheat ('Rose' hard red winter wheat) grown in hydroponic solution showed that feeding by the RWA significantly retarded seminal root growth; the degree of inhibition of root growth due to RWA was similar to that caused by the greenbug (GB) and the bird cherry oat aphid (BCO) at the same population densities. Feeding by RWA on greenhouse-grown spring wheat reduced grain yield significantly more ($P<0.01$) than either GB or BCO. Neither pot size nor soil fertility level significantly influenced ($P>0.05$) yield losses caused by aphid feeding.

Because insect-resistant small grains are not yet available for RWA and because involute leaves caused by aphid feeding shields the pests from contact insecticides, there is an immediate need to research other crop production alternatives that could aid in reducing the economic loss due to this insect.

Results of recent greenhouse experiments completed at NGIRL, Brookings, SD, have shown that nitrogen fertilization ameliorates wheat plant damage and yield loss caused by RWA infestation (Riedell, 1990). These results suggest that nitrogen fertilization might be a useful strategy for limiting yield loss caused by RWA in plants that are deficient in nitrogen. Further research is needed to document the economic benefit and environmental risk of this strategy.

For example, benefits and risks of nitrogen fertilization amelioration of RWA-induced yield loss should be documented under field conditions. A split-plot experimental design with nitrogen fertilization level as the main plots and RWA infestation as the subplots is required. Treatment effects on plant height, tiller number, shoot biomass, leaf area, head number, and yield should be assessed. The NGIRL contains adequate facilities for rearing insects for field use and has the necessary field equipment and cages to conduct this study. Funding is required for technical assistance in performing the day to day operations associated with this experiment.

Experiments concerning the characterization of the physiological mechanisms that lead to plant damage and yield loss in plants infested with RWA are in progress. These experiments are being performed in cooperation with scientists from the State Agricultural Experiment Station at South Dakota State University. The specific goals of these experiments are to characterize RWA plant damage and yield loss under controlled conditions, and to search for specific mechanisms that impact physiological processes (shoot and root growth, photosynthesis, water relations, nutrition) and cause yield loss. Improved cultural practices to reduce RWA yield loss and bioassay protocols for screening plants for RWA resistance are the tangible benefits of this experiment.

Some progress has been made in understanding the physiological basis by which the RWA damages barley plants (Riedell, 1989). Leaves infested with RWA had lower relative water content, reduced stomatal conductance, more negative water potential, lower levels of chlorophyll, and higher levels of amino-N. Taken together, these observations show that RWA infestation causes drought-stress symptoms in leaves of infested plants even in the presence of ample root moisture. Longitudinally rolled leaves, a symptom of RWA infestation, may result because the infested plant is suffering from drought stress. Further investigation is needed to elucidate the mechanisms involved in causing drought stress in infested plants.

When drought stress was imposed on plants previously infested with RWA, accumulation of osmoregulatory substances was reduced. This reduction, which is related to decreased ability to successfully adjust to drought stress in RWA-infested plants, was probably caused by chloroplast disruption by the aphid toxin. Further experiments concerning RWA damage and chloroplast degeneration, and the role these play in drought stress adjustment in cereals are needed. The biochemical nature of the phytotoxic substances and of the mechanisms responsible in limiting the accumulation of osmoregulatory substances in aphid-damaged tissue should be the topic of future research. However, at the present time, this research is limited by lack of a proper level of funding.

Host Plant Resistance

Mission: To identify resistance sources, study the nature of this resistance, and cooperate with the Germplasm Development program in the development and release of RWA-resistant small grain germplasm.

Stillwater, OK

The Host Plant Resistance and the Small Grain Germplasm Development programs continue to work very closely and continue to have a common primary mission, that is, the release of both wheat and barley germplasm lines that are resistant to the RWA. An additional mission is to determine the mechanisms of resistance, including genetic, biochemical, and physical mechanisms of resistance. Knowledge about mechanisms of resistance will aid scientists in selecting appropriate RWA-resistant wheat or barley parents for host plant resistance breeding programs. Damage from other serious small grain pests such as the cereal leaf beetle and Hessian fly on wheat and the greenbug on barley are currently minimized with the use of resistant cultivars that were developed in previous cooperative ARS-State programs. In addition, greenbug-resistant wheats will be available in the near future. Thus we believe that the development of RWA-resistant wheat and barley germplasm is a practical and realistic goal. Not only will growers save the expense of insecticides, but possible chemical hazards to the environment will be avoided.

Because the RWA has now been detected in the vicinity of our laboratory, we have moved our mass screening tests from an isolated plant growth chamber to the greenhouse, where we can test considerably larger groups of wheat and barley lines for RWA resistance. It appears that the greenhouse is better than the growth chamber for detecting lower levels of RWA resistance. For example, last year we reported that wheat lines previously noted as resistant by South African scientists were susceptible in our growth chamber tests. In contrast, these lines and a line reported to be resistant in Colorado tests exhibited varying levels of RWA resistance in the greenhouse tests. These lines have been entered in the RWA-Small Grain Germplasm Development program for crossing with adapted wheat cultivars. In many field situations, even low levels of RWA resistance can be quite valuable. During the current testing year, wheat lines from areas of the world where the RWA and wheat are thought to have originated will be tested against the RWA to search for higher levels of RWA resistance.

Last year, we reported finding RWA resistance in triticale. Since triticale is a wheat-rye cross, plant breeders can utilize this resistance in developing RWA-resistant wheat. Recent tests on the mechanisms of resistance of these lines indicate a high level of tolerance. In addition, aphid reproduction on one of these lines is extremely low, indicating a high level of antibiosis--so high, in fact, that it is difficult to keep RWA's on the plants.

This year we are putting additional emphasis on searching for RWA resistance in barley, which is actually damaged to a greater extent than is wheat. The RWA is a very serious pest for producers of both feed and malting barley. In fact, Minnesota is currently the only major barley-producing state that does not yet have the RWA. Because both barley and the RWA have apparently coexisted in some areas of the Mediterranean and the Middle East for many years, it seemed prudent to test barleys collected from this part of the world for RWA resistance. With this in mind, the late Dr. D. H. Smith, Jr., former curator of the USDA-ARS National Small Grain Collection, selected 524 barley accessions from a total of eight countries to be tested for RWA resistance at Stillwater. Fifteen lines were found to have varying levels of resistance and were selected from these tests

for further evaluation. Additional tests were performed with nine of these lines to determine the mechanisms of resistance. The lines and their sources are: PI 366444, PI 366447, PI 366449, PI 366450, PI 366453 (Afghanistan); CI 1412, PI 430140, PI 430142 (Iran); and PI 447219 (Spain). Plant survivors of these tests have been saved for the barley RWA plant resistance breeding program. Now that RWA resistance has been detected in barley, we believe that the resistant sources can be rapidly introgressed into adapted barley for release as RWA-resistant germplasm. However, we will continue to search for additional sources of resistance in barley. Arrangements have been made with USDA-ARS National Small Grain Collection personnel to test the entire common barley (*Hordeum vulgare*) collection of about 12,000 lines.

Various rye (*Secale cereale*) lines are often used by wheat breeders as a source of insect and disease resistance. In addition, the rye crop is sometimes damaged by the RWA, thus RWA-resistant rye lines could be used by plant breeders in developing resistant rye germplasm as well. During the winter of 1988-89, we tested all available rye lines from the ARS National Rye Collection for RWA resistance in the greenhouse. Of the 1238 lines tested, many showed some levels of resistance. Eight of the best have been saved for seed increase, crossing, and further testing.

The Stillwater ARS RWA Host Plant Resistance project cooperates closely with other scientists both nationally and internationally. During the year, a cooperative research program with Dr. F. du Toit of Bethlehem, South Africa, was initiated to compare the reproductive potential of South African RWA's with North American RWA's using the same wheat cultivar and the same experimental conditions. The only difference is that Dr. du Toit is testing aphids from his country and we are testing aphids from ours. This will help us determine if biotypic variation occurs between these populations. We also cooperated with scientists from 11 other locations in North America, conducting the first uniform RWA seedling screening test, and we have made plans to participate in a second test with additional locations next year. The purpose of this test is to exchange seed of resistant entries and evaluate the performance of these entries under RWA infestations at the different locations.

We believe that considerable progress has been made during the past year in the RWA Host Plant Resistance program. The Small Grain Germplasm Development program has made a large number of crosses between wheat and various resistant sources. In addition, the discovery of RWA resistance in barley was an exciting event for our project this year, and we are much more optimistic about the prospects of developing RWA-resistant barley germplasm than we were a year ago.

Small Grain Germplasm Development

Mission: To develop and release RWA-resistant small grain germplasm for use by both public and private breeders.

Stillwater, OK

The Small Grain Germplasm Development project began working with the RWA approximately three years ago. Several *Triticum tauschii, T. umbellulatum*, and triticale lines were among the resistance sources first identified by our cooperating Host Plant Resistance program. As soon as these lines were identified, an interspecific crossing program was begun to introgress resistance from the alien wheat-related species into a hexaploid wheat background. These types of crosses usually require the use of the embryo rescue technique for successful recovery of hybrid F1 plants (see last year's annual report).

Most of the rescued embryos were placed on media (MS basal medium containing no 2,4-D) for immediate plant regeneration. The remainder were placed on media (MS basal medium with 4.5 M 2,4-D) for callus induction, and these were then subjected to prolonged periods of time in callus culture prior to plant regeneration. In addition to the F1 hybrid embryos that were rescued, some of the selfed triticale embryos were also rescued and placed on callus-inducing media. At this time it is unknown whether this material will be of any practical use, but since extended periods of time in callus culture are known to induce translocations, this may be a means of incorporating resistance into the wheat genome, especially if the resistance in the triticale is controlled by its rye component.

To date, our interspecific breeding lines include approximately 400 lines derived from crosses with six different *T. tauschii* lines, approximately 300 lines derived from crosses with eight different triticales, and three lines derived from a cross with one *T. umbellulatum* line. All of this material is currently being screened for resistance to the RWA.

Unfortunately, most of the breeding material in the interspecific breeding project will not be of use in the near future. Problems associated with these crosses include interspecific incompatibility, hybrid necrosis, high levels of male sterility, and the possible masking of alien genes in a hexaploid wheat background. Most of this material will require a much longer timeframe prior to the eventual release of RWA-resistant germplasm that can be utilized in a traditional wheat breeding program. However, the ultimate value of this material could be very important. Each source may provide a different resistant gene or genes that could be pyramided into a single cultivar, thus providing a more horizontal type of resistance that would prove beneficial should biotypes of the RWA arise.

Although most of the interspecific crosses have been difficult to work with, some of the most promising material in the project involves interspecific crosses with PI 149898, a triticale collected in the Soviet Union. While this line does not have the same high level of resistance to the RWA as the other triticales, it definitely does have a usable level of resistance. The reasons it is so promising are the ease with which it crosses with wheat (there is no need for embryo rescue) and the high levels of fertility in its interspecific progeny. Preliminary screening tests indicate that the F1 has the same level of resistance as the resistant parent. We have approximately 212 breeding lines derived from various crosses between PI 149898 and

'Chinese Spring', 'Bobwhite', and 'Pavon'. These include 17 BC1 lines, 28 F2 lines, and 167 F3 lines. All are currently being screened for resistance levels. To date, the crosses between PI 149898 and 'Bobwhite' look especially good.

In addition to our interspecific breeding project, we also have been utilizing a soft white winter wheat (PI 372129) originally collected in the Soviet Union. This wheat was first identified as being resistant to the RWA following a natural infestation of a drought field study in Colorado. Our crosses with this line have primarily used 'Chisholm' as the recurrent parent. To date, we have obtained F1, BC1, and F2 progeny. A genetic study using this material is currently being conducted in the greenhouse. Progeny are being grown in flats, infested with the RWA, and screened using our standard techniques. Information regarding the number of genes controlling this resistance and the type of inheritance involved should be available soon.

We feel that the wheat germplasm development project has made significant advances within the past year. It appears that the most promising sources of resistance for wheat, in terms of expediting germplasm release, appear to be in the PI 149898 triticale and PI 372129 wheat. Both of these lines have very similar reactions to the RWA, in that leaves remain unrolled, there is little or no streaking, and plants are able to tolerate heavy infestations much longer than any available wheat cultivars commonly grown in the United States. This is not to say that these lines are totally immune to the RWA, but their ability to tolerate heavy infestations of the insect and maintain growth with unrolled, nonchlorotic leaves greatly increases the probability of successful control via an integrated pest management program utilizing host plant resistance, effective predators and parasites, cultural control methods, and use of insecticides under severe RWA attack.

Until recently, we have been solely concerned with the development of RWA-resistant wheat germplasm. The identification of RWA-resistant barley lines by our Host Plant Resistance project has added an exciting new dimension to the Germplasm Development project. Excessive heat in summer greenhouses meant that this new portion of our project had to be delayed until now, but with the coming crossing season we will begin incorporating RWA resistance into adapted barley germplasm.

Alternate Hosts for Russian Wheat Aphid

Mission: To identify and characterize RWA-resistant germplasm lines that may serve as breeding resources for both cool- and warm-season cereal, turf, range, and conservation grass species.

Stillwater, OK

From seed provided by the Regional Plant Introduction Station, Pullman, WA, we are evaluating and identifying RWA resistance in *Agropyron* (1270 entries), *Elymus* (308 entries), *Hordeum* (106 entries), and *Secale* (24 entries). The selection criteria for resistance has been to choose genotypes that do not exhibit RWA feeding damage symptoms such as leaf streaking, leaf rolling, and trapping of new leaves. In addition, we are selecting genotypes that are tolerant to large populations of RWA that would normally kill wheat, barley, rye, or oats. We are also selecting genotypes that support no or low populations of RWA. In spite of the fact that many of the entries that we are testing are very susceptible to RWA, high levels of resistance in a few entries of *Agropyron, Elymus*, and *Hordeum* have been identified. Some of these resistant entries will cross with wheat and/or barley. As a result, research has been initiated to use "wide cross" breeding techniques to introduce the RWA resistance into these important cereal crops.

Two entries of *Agropyron repens* and the wheatgrass hybrid *A. repens* x *A. spicatum* were tolerant (resistant) to feeding damage by RWA. Although most *A. repens* entries had low levels of damage from RWA feeding, the level of susceptibility still ranged widely from 2.3 (PI 440665) to 9.0 (PI 172686). Entries from *A. spicatum* sustained a high degree of damage from RWA feeding, and were not significantly different from the susceptible 'TAM-101' wheat, *Triticum aestivum*. Based on this fact, it is quite apparent that *A. repens* provided the resistance to the interspecific hybrid wheatgrass.

This is the first report of genetic resistance to RWA and its transfer in forage grasses. It may be possible to use *A. repens* entries with high levels of RWA resistance to make interspecific and intergeneric crosses to a broad range of wheatgrasses for the purpose of developing RWA-resistant wheatgrass.

The specific components of resistance (tolerance, antibiosis, nonpreference) in the resistant *A. repens* entries have not yet been evaluated. Therefore, we do not know if the RWA resistance is physiological or physical in nature. Further research is needed to determine the specific nature of the resistance to the RWA in *A. repens*, which may aid other scientists in finding RWA resistance in other crops.

Insect Genetics

Mission: To conduct national and worldwide genetic studies on the RWA and its parasitoids.

Stillwater, OK

An insect genetics program has been initiated to investigate the population genetics of the RWA and to fingerprint its native and exotic parasitoids. These studies on the genetics of RWA are being conducted on a national and worldwide scale. We are currently maintaining 30 RWA colonies that were collected throughout the western United States. Samples of RWA from Syria, Jordan, France, Turkey, and the Soviet Union have been obtained from the EPL, Behoust, France, via the ARS quarantine facility at Newark, DE. Arrangements have also been made to obtain samples from Morocco, South Africa, Mexico, Canada, Spain, and Ethiopia.

The genetic variation of RWA within and between various geographic locations is being studied using both isozyme variation and molecular variation in the rDNA cistron. The relationship between genetic distance and geographic distance will be determined. This will aid in our understanding of the intercontinental migration/introduction patterns of RWA, where our U.S. population originated, why resistant cultivars perform differently from one geographic area to another, and which areas may have more effective sources of plant resistance and exotic parasitoids.

Currently, RWA colonies are being increased and stored in liquid nitrogen so that we can start on a genomic library for the molecular DNA work. The isozyme studies are in progress, and over 18 enzyme systems have been examined for activity on the U.S. collections using starch gel electrophoresis. Eight of those enzymes tested had detectable levels of activity, and preliminary results found these enzymes to be monomorphic between collections. New collections are continually being added to this study in an attempt to find isozyme variation. Those RWA colonies that are found to exhibit genetic variation will then be investigated further to determine if they perform differently on resistant and susceptible small grains.

Dr. J. Slosser, Texas Agricultural Experiment Station, Vernon, TX, provided seven RWA colonies in which he found varying levels of virulence to susceptible wheat and hypothesized that biotypic variation may exist in RWA. However, at the time of his study, resistant germplasm was not available to test this hypothesis. Therefore, we will investigate these RWA isolates, and other isolates that are determined to differ genetically, on several of the resistant wheat and triticale cultivars to determine if biotypic variation exists in our U.S. population.

Electrophoretic fingerprinting of native and exotic parasitoids is being conducted in cooperation with Dr. W. Steiner, ARS Biological Control of Insects Research Lab, Columbia, MO. The limited number of imported *Aphidiidae* that we have investigated so far have very distinct enzyme patterns in comparison with two common native aphid parasitoids, *Lysiphlebus testaceipes* Cresson and *Diaeretiella rapae* (McIntosh). Fingerprinting RWA parasitoids looks very promising, but we have not been able to obtain enough native or exotic parasitoid collections to make any formal conclusions. There is an urgent need for obtaining as many exotic and native *Aphidiidae* collections as possible since a shotgun approach of releasing unidentified and biologically uncharacterized parasitoids in the field is being used. Many of the exotic parasitoid species are the same species or are taxonomically undistinguishable from those species indigenous to the United States. Therefore, it could be impossible to document the establishment and dispersion of the released parasitoids.

Columbia, MO

One goal of the Genetics Unit at the ARS Biological Control of Insects Research Laboratory is to furnish information on the genetic background of parasites and predators attacking RWA, and to follow genetic events occurring in introduced colonies of these organisms after colonization in the United States. Allozyme analysis of native and exotic parasitoids of the RWA is being conducted in collaboration with G. Puterka, insect genetics, and D. Reed, biocontrol, at Stillwater. Laboratory colonies of *Diaeretiella rapae* from Colorado, Greece (three populations), and Pakistan reveal fixed genetic differences between all populations. The differences involve different gene loci. Thus, Greece T89042 differs from Greece T89063 and Pakistan T89029 at alpha-glycerophosphate dehydrogenase; the former fixed for a slower electrophoretic allele. They also differ at phosphoglucomutase, Greece T89042 being fixed for the same allele found in the Colorado colony and Pakistan, but Greece T89063 having a slower migrating allele, and a third Greek population (T89040) segregating for the T89042 allele, plus a third allele slower than that of T89063. Greece T89063 and Pakistan T89029 also share a fast-migrating allele at two different hexokinase genes, while Greece T89040 and T89042 share slow-migrating alleles at these two genes. No differences were observed at a second alpha-glycerophosphate dehydrogenase locus, two malate dehydrogenase loci, a gene coding for aldolase, and the glycerophosphate-3-dehydrogenase locus. Although only nine loci were examined, half display some type of difference, suggesting the fixed differences in these populations, which were recently removed from nature, are not due to chance founding events. We suggest from these findings that *D. rapae* consists of a sibling species complex with at least three species. These have little or no information currently available on differences in morphology, anatomy, life history, or host preference. The different genetic types' differential ability to parasitize RWA is suggested as a future project.

Simulation Modeling

Mission: To develop quantitative technology for incorporation into management decision support systems.

Brookings, SD

The following biological studies were conducted on RWA to provide information needed to improve a computer simulation model of RWA population dynamics: (1) The effect of population density of RWA on its population growth rates, size, reproductive rate, and incidence of winged adults; and (2) The effect of age of spring wheat and spring barley on RWA population growth rate. Results of these studies have been analyzed and are being incorporated into the existing RWA computer simulation model.

Biosystematics

Mission: To provide identifications and verifications for RWA and its natural enemies.

Beltsville, MD

During FY89, Dr. M. Stoetzel provided identifications and verifications for *Diuraphis noxia* (Mordvilko). Additionally, she gave the invited talk "*Diuraphis noxia*, the Russian Wheat Aphid: What We Know and What We Need to Find Out" in the symposium "New Pests and Their Routes of Entry" held October 3, 1988, during the Eastern Branch Meeting, Entomological Society of America, Syracuse, NY. Dr. Stoetzel was invited to give the talk "The Russian Wheat Aphid, *Diuraphis noxia* (Mordvilko)--a dangerous new pest in the United States" at a meeting of the Maryland Entomological Society, Catonsville, March 17, 1989.

From April 17-22, 1989, Dr. Stoetzel worked at the ARS Plant Science Research Laboratory in Stillwater, OK. Two days were devoted to field-collecting aphids from wheat, barley, and various species of *Bromus*. Laboratory colonies were also sampled. From April 24-28, 1989, Dr. Stoetzel worked at the Texas Agricultural Extension office in Lubbock. Collections of aphids were made in wheat fields heavily infested with RWA and from volunteer wheat and species of *Bromus* growing in fields and along roadsides. These aphid samples have not been prepared and slide mounted because Dr. Stoetzel has been without any technical support since April 1989. When the aphids have been mounted, morphometric studies will begin.

From September 5-8, 1989, Dr. Stoetzel had the opportunity to work at the ARS European Parasite Laboratory, Behoust, France. Colonies of *D. noxia* collected from several locations throughout Europe are being maintained at EPL. On September 7, while taking samples from these laboratory colonies, Dr. Stoetzel noticed, among several "normally colored" nymphs, one that had a noticeably darker head and completely black antennae. This specimen turned out to be an apterous male of *D. noxia*. The original collection data for the colony is Kishinev and vicinity, Moldavia, USSR, May 28 to June 2, 1989, wheat and barley, T. Poprawski and F. Gruber. Since its original collection, this colony has been maintained at EPL at 12 hours light/12 hours darkness at 20-21°C. Despite continued search, Dr. Stoetzel found no additional males, but has now received word that others have been found in this laboratory colony by the EPL staff. When the aphids have been mounted, they will be included in the morphometric study of species in and related to *Diuraphis*.

Planned trips to British Columbia, Canada, to search for *D. nodulus* (Richards) were cancelled because funds for the trips were not available. If funds become available, trips will be made in June and September 1990.

Identification of Braconid parasitoids was made by P. Marsh, who receives specimens from both the overseas laboratories and from researchers within the United States, including ARS, universities, and APHIS. During 1989, a great percentage of the specimens received were identified as *Diaeretiella rapae*, both the exotic species and those collected from within the United States. For this reason, perhaps more biocontrol research should be devoted to this species. A key to the genera of both primary and secondary parasitoids of RWA was published in the Fall RWA Newsletter (Marsh et al., 1989) to aid researchers in making preliminary identifications. M. Schauff is cooperating with taxonomists at Texas A&M University on identification of the Apheliinid group. A close cooperative effort is also maintained with Dr. P. Stary, Czechoslovak Academy of Sciences, on identification of Braconid parasitoids.

Biocontrol

Mission: To collect, study, and release exotic natural enemies of the RWA into the RWA-infested grain growing regions of the United States as a control strategy.

Stillwater, OK

Research on biocontrol of RWA at the Stillwater laboratory is concerned with improved rearing techniques for exotic parasitoids and determination of critical biological properties of these insects prior to widespread releases. Parasitoids are collected by the ARS European Parasite Laboratory, forwarded to the ARS Beneficial Insects Research Laboratory for quarantine, and then shipped to Stillwater. Specimens of all Aphidiine isolates collected are sent to our laboratory. These isolates are cultured on RWA in controlled environment chambers until colonies are well established and are then increased in screen cages in the greenhouse for research purposes.

The following species of exotic parasitoids are presently in culture at the Stillwater laboratory:

Praon necans (or *abjectum*)	Moldavia, USSR
Diaeretiella rapae	France (5 isolates)
D. rapae	Syria (4 isolates)
D. rapae	Turkey (2 isolates)
Aphidius matricariae	Turkey

The laboratory is also in the process of obtaining additional colonies of *Aphidius* spp. from Texas A&M University for genetic studies.

Growth chambers with controlled temperatures and light have been utilized successfully for longterm rearing of parasitoids, but greenhouse rearing has only been successful during the fall, winter, and spring seasons. Problems during the summer include diseases of host plants, massive declines in RWA populations for unexplained reasons, and poor reproduction of parasitoids. A few small growth chambers are available for rearing in the summer. Small cages, 3 x 2.5 x 6.3 cm, were constructed for use in these chambers and have proved to be satisfactory. These cages have screen on all four sides for necessary ventilation, and utilize 3-inch pots.

The research on biological properties of the exotic parasitoids has included the study of searching rates and host preference. Other studies undertaken have been tritrophic relationships and feeding monitor studies of parasitized aphids. The tritrophic experiments included relationships between *Diaeretiella rapae* and RWA on two triticale lines, two wheat lines, and one oat line. Results indicate that the parasite has a large impact upon the aphid population and subsequently upon the growth characteristics of the host plants. Further research is planned to more critically examine these relationships. The feeding monitor tests were accomplished using an electronic feeding monitor that allows quantification of aphid salivation and ingestion. These experiments may aid in determining the overall effect of aphid parasitism in the field.

Further work is planned to determine biological parameters of introduced parasitoids in order to select the most promising for field releases. The first releases are scheduled for the spring of 1990 in areas of Oklahoma, Texas, and Colorado. These releases will be made within field cages in areas where previous releases have not been made. Recoveries of parasitoids after release from the cages will be utilized in isozyme studies to determine if the insects recovered are progeny of

released parasitoids. Studies of distribution over time and distance will also be conducted in cooperation with W. Steiner (Columbia, MO) and G. Puterka (Stillwater).

A laboratory for research on fungal pathogens has been established, and recruitment for a research associate insect pathologist is underway. To date, a qualified applicant has not been found. It is hoped that this laboratory will soon be operational, and research on RWA pathogens will be initiated in cooperation with EPL and other institutions.

We feel that the identity of exotic parasitoids should be substantiated prior to widespread releases into the ecosystem that will likely contain analogous species. Exotic parasitoids that have been collected and shipped to the United States include *Aphidius matricariae, Diaeretiella rapae, Praon* spp., *Ephedrus* spp., and *Aphelinus* spp., all of which have been introduced into the United States during previous projects for the biological control of other aphids. Most of these are known to be present and have been referred to as "native or indigenous" species. This is a misnomer and has led to some confusion. A more appropriate term might be "immigrant spp." Characterization, both isozymic and morphometric, should be accomplished on all exotic parasitoids as they arrive in the United States, and upon the extant aphidophagous parasitoids prior to releases of the exotics. A protocol has been set up for shipment of endemic and nouveau-endemic specimens to the ARS Stillwater laboratory and to the APHIS biocontrol laboratory in Mission, TX, for increase and storage in liquid nitrogen. These will be used for genetic studies and for shipment to taxonomic specialists for morphometric identifications. Exotics are cultured and stored for the same purpose. The Stillwater biological control laboratory is committed to this work and actively supports all aspects of the research.

Behoust, France

Foreign Exploration

Exploration for biological control agents for RWA was conducted by the European Parasite Laboratory (EPL) in cooperation with entomologists of the International Center for Agricultural Research in the Dry Areas (ICARDA, Aleppo, Syria), the All Union Research Institute of Biological Methods in Agriculture (Kishinev, Moldavian SSR), the Kirghiz Agrochemical Consortium (Frunze, Kirghiz SSR), the All Union Institute for Plant Protection (Leningrad, USSR), the V. I. Lenin All Union Academy of Agricultural Sciences (Moscow, USSR), the All Union Research Institute for Plant Quarantine (Moscow, USSR), the University of Idaho, the Washington State University (WSU), the National Institute for Agronomic Research (Rabat, Morocco), the National Institute for Agronomic Research (Antibes, France), and the Technical High School of Agronomic Engineers (Cordoba, Spain).

Areas surveyed by EPL included Spain (March 28-April 7), Morocco and Spain (April 21-30), Moldavia (May 25-June 15), southern France (June 5-8, June 19-22, July 3-8), Kirghizia (August 15-September 16), Moldavia, Crimea, and southwestern Ukraine (October 21-November 8). S. Halbert of the University of Idaho joined EPL staff on the latter trip, R. Miller of ICARDA surveyed Syria for EPL (May-June), K. Pike and L. Tanigoshi collected for EPL and their institution (WSU) in Jordan (May).

Barley, wheat, oats, sorghum, and wild Poaceae were searched for RWA and other cereal aphids in sampled areas. Emphasis was placed on RWA whenever possible. In sampled fields, meadows, and ranges, RWA was found sporadically and in low numbers as determined from visual inspection of plants. Exceptions were Spain where RWA was not recovered and the Kirghiz Inner Tien Shan where heavy outbreaks of RWA were observed in barley fields and wild grasses as well. RWA and other cereal aphids, and their parasites, predators, and pathogens, were collected and hand-carried or shipped (from Syria and Jordan) to EPL. The natural enemies found associated with or reared and isolated from RWA were shipped to the United States. Biocontrol agents shipped to the United

States as of 30 October 1989 are listed in Table 1. Parasitoids collected in Kirghizia are being maintained in culture at the Kishinev's laboratory where EPL established colonies of RWA. These parasitoids and the biomaterial collected during the fall survey of Moldavia, Crimea, and southwestern Ukraine will be hand-carried to EPL in early November and then shipped to the United States. Representative parasitoids and fungal pathogens collected in 1989 were retained at EPL for research purposes.

Other Activities

An indexed bibliography of over 450 references has been prepared (Poprawski, 1990). The manuscript is in the review process and will be available for distribution early in 1990.

The influence of geographic origin, food plant, temperature, and photoperiod on the biology of RWA is being studied in the laboratory. Biological parameters under study include morphogenesis, developmental rate, natality, survival, and duration of life stages. To date, Kirghiz, Turkish, and U.S. lines of RWA have been monitored at three temperatures, on two food plants, and at one photoperiod regime. Data analysis indicates that all parameters studied are strongly influenced by temperature and geographic origin.

Eight pure lines of RWA have been established in the laboratory. The aphids are maintained at 21°C, 60-70% RH, and a 16:8 photoperiod. The founder colonies of these lines, possibly biotypes, have been collected in Turkey, Syria, Jordan, Moldavia, Kirghizia, United States, and France (two lines). These aphids are being used in our biology studies and in experiments on the susceptibility to fungal diseases. M. Stoetzel, Beltsville, used these aphids in morphometric studies during her visit to EPL in August-September 1989. EPL has provided G. Puterka, Stillwater, with founder colonies of RWA to be used in genetic studies. The Moldavian line has produced apterous males and oviparae, morphs that will mate and produce overwintering eggs. These important findings will deepen our knowledge of RWA biology and control.

Bioassays have shown RWA to be highly susceptible to several strains of entomophthoralean fungal species isolated from RWA, other aphids, and cicadellids. Fungal species tested so far include *Pandora neoaphidis, P. delphacis, Zoophthora radicans*, and *Conidiobolus thromboides*. Other fungal species isolated in 1989 from RWA yet to be assayed include *Entomophthora planchoniana, Triplosporium fresenii*, and *Verticillium* sp. Promising strains will be shipped to D. Reed, Stillwater, and R. Humber, Ithaca, for field testing.

Experiments are in progress with *Aphelinus asychis* on heritability of search rate. Also the effect of mass rearing versus isofemale lines on genetic change under laboratory rearing is being tested with *A. asychis, A. varipes*, and *Diaeretiella rapae*.

Experiments on functional response (search rate versus host density) are in progress, and experiments on preference of parasitoids of RWA for various cereal aphids are planned.

Models of the Allee effect in classical biological control have been developed, and experiments to test the predictions of the models with parasitoids of RWA are being planned.

Table 1. Disposition of biocontrol agents collected from *Diuraphis noxia* obtained from 1989 collections

EPL code	Species	Source location	Lab host	Recipient	Number and life stage
		PARASITES			
	Aphelinus				
61	*A. asychis?*	Antibes, Alps Maritimes, France	*D. noxia*	BIRL	500 Mummy-plant*
62	"	"	"	"	430 Adults
76	"	"	"	TA&M	133 Mummies
87	"	"	"	BIRL	1450
86	"	"	"	"	934
69	"	"	"	TA&M	400 Mummy-plant*
60	*A. varipes?*	Kishinev, Moldavia, USSR	"	BIRL	118 Mummies
67	"	Seronon, Alps Maritimes, France	"	TA&M	30 Mummies
78	"	"	"	"	13 Mummies
	Aphidius				
56	*A.* sp.	Kishinev, Moldavia, USSR	*D. noxia*	*BIRL*	*9 Mummies*
57	"**	*Antibes, Alps Maritimes, France*	"	"	*69 Mummies*
66	"**	"	"	*TA&M*	*97 Mummies*
75	"	"	"	"	*628 Mummies*
77	"	"	"	"	*70 Mummies*
	Diaeretiella				
51	*D. rapae*	Allepo, Syria	*D. noxia*	BIRL	69 Mummies
58	"	"	"	"	55 Mummies
65	"	"	"	TA&M	26 Mummies
72	"	"	"	BIRL	30 Mummies
79	"	"	"	TA&M	86 Mummies
83	"	"	"	"	134
63	"	Antibes, Alps Maritimes, France	"	BIRL	250 Mummy-plant*
64	"	"	"	"	100 Mummy-plant*
71	"	Seronon, Alps Maritimes, France	"	"	120 Mummies
84	"	"	"	"	105
85	"	"	"	"	752
	Praon				
59	*P. necans* or *abjectum*	Kishinev, Moldavia, USSR	*D. noxia*	BIRL	49 Mummies
81	*P. volucre*	Turkey	*D. noxia*	TA&M	301
	Ephedrus				
80	*E. plagiator*	Turkey	*D. noxia*	TA&M	502

Table 1. Continued

EPL code	Species	Source location	Lab host	Recipient	Number and life stage
		PREDATORS			
	Coccinella				
39	*C. 7-punctata*	Kishinev, Moldavia, USSR	*S. graminum*	BIRL	210 Adults
53	"	Alps Maritimes, France	"	"	37 Adults
88	*C. 13-punctata*	Kirghizia, USSR	"	"	207 Adults
	Chryosopa				
70	*C. carnea*	Disi, Jordan	*S. graminum*	BIRL	30 Cocoons
	Propylea				
40	*P. 14-punctata*	Kishinev, Moldavia, USSR	*S. graminum*	BIRL	13 Adults
52	"	Alps Maritimes, France	"	"	5 Adults
	Adonia				
41	*A. variegata*	Kishinev, Moldavia, USSR	*S. graminum*	BIRL	81 Adults
54	"	Alps Maritimes, France	"	"	22 Adults
89	"	Kirghizia, USSR	"	"	580 Adults
	Hippodamia				
42	*H. 13-punctata*	Kishinev, Moldavia, USSR	*S. graminum*	BIRL	12 Adults
90	"	Kirghizia, USSR	"	"	28 Adults

BIRL = ARS Beneficial Insects Research Laboratory, Newark, DE; TA&M = Texas A&M University, College Station, TX.

*Mummies on plant material

**Definite identification is pending; possibly *Diaeretiella rapae*.

Brookings, SD

Basic research and evaluation of coccinellids imported for RWA biocontrol is underway. Studies were conducted to determine the effects of temperature and several species of aphids as exclusive food for immatures on immature developmental rates and survival, and reproduction and survival of adults of *Scymnus frontalis*, a coccinellid imported from Turkey for RWA control. *Scymnus frontalis* has a slightly higher developmental threshold than most nearctic coccinellids that have been studied, perhaps indicating its adaptedness to subtropical climates. Immature development, fecundity, and survival of *S. frontalis* is similar regardless of whether it is fed RWA, greenbugs, or pea aphids during its immature stage. Field cage studies were conducted to determine the effectiveness of *S. frontalis* and *Propylea 14-punctata* imported from Turkey relative to an indigenous coccinellid, *Hippodamia convergens*, as predators of cereal aphids under the environmental conditions of eastern South Dakota. Due to budgetary limitations inhibiting extensive travel and the absence of field populations of RWA in eastern South Dakota, we used greenbugs rather than RWA in our field cage studies. Greenbug populations in cages were reduced more by *H. convergens* than by *S. frontalis* or *P. 14-punctata*. We developed time-efficient yet accurate methods for sampling predatory coccinellid populations in wheat fields. Reliable sampling methods are needed to facilitate evaluation of the RWA biocontrol program. We demonstrated that with knowledge of only the number of lady beetles per sweep in a 180-sweep sample taken with a standard sweepnet, estimates that account for about 75% of the variation in absolute population density of lady beetles can be obtained. Simultaneous measurement of a few environmental variables can produce estimates that account for 80-90% of the variance in absolute density. We are analyzing an historical database of 15 years of predator sampling in corn, small grains, and alfalfa at three geographically separated locations in eastern South Dakota to explore changes in predator communities within the crops among years and locations. Specifically, we have derived ordinations of predatory insect communities for each site each year using correspondence analysis. Trends in community change over time and among locations are being examined based on the ordination results. The results of this study will serve as a baseline from which to evaluate the impact of introduced natural enemies for RWA biocontrol on communities of indigenous natural enemies.

Newark, DE

<u>Parasite Shipments</u>

Twenty-one shipments of four Hymenopterous parasite species, representing three generations in two families, were processed through BIRL-Quarantine from EPL, Behoust, France. This material was emerged, sexed, identified, and transhipped to one APHIS (Mission Biological Control Laboratory, Mission, TX) and one ARS (Plant Science Research Laboratory, Stillwater, OK) laboratory. Identifications of the material released (for additional culture and study) were confirmed by P. Marsh or M. Schauff (Beltsville). A total of 15 shipments (ca. 2125 specimens received alive) were made through October 16, 1989 (see Table 2).

One shipment of ca. 30 cocoons of *Chrysopa* sp. (possible *carnea*) was also received; however, no emergence has been noted, and the material will be placed into cold storage (overwintering) December 1, 1989.

Predator Shipments

Ten shipments of predaceous coccinellids representing four species were received from EPL in 1989. All biotypes were cultured on pea aphid, and as material became available, a total of 35 shipments were made to APHIS, Biological Control Laboratory, Niles, MI, for further propagation, distribution, and study (see Table 2). The two species of *Scymnus* shipped out represented material from colonies received in 1988 and maintained in culture since then. These out-going shipments contained 6215 specimens, representing six species and nearly all biotypes received.

Table 2. Summary of 1989 shipments related to Russian wheat aphid

Destination/species	Number of shipments	Total number specimens (females)	Collection localities
	PARASITES		
To APHIS, Mission, TX			
Aphelinus asychis	4	1358 (954)	France
Aphelinus varipes	1	32 (29)	USSR
To ARS, Stillwater, OK			
Diaeretella rapae	9	722 (507)	France/Syria
Praon sp.	1	13 (5)	USSR
	PREDATORS		
To APHIS, Niles, MI			
Coccinella septempunctata	10	1767 (882)	France/USSR
Propylea quatuordecimpunctata	4	263 (136)	USSR
Hippodamia variegata	8	1221 (644)	France/USSR
Scymnus rubromaculatus	3	440 (224)	France
Scymnus frontalis	2	216 (109)	France/Turkey

Ithaca, NY

R. Humber provided fungal cultures and information about the biology and handling of fungal pathogens of RWA and other cereal aphids to several laboratories throughout the United States and Canada. The most commonly observed fungal pathogen of RWA in North America (as well as in Eurasian endemic habitats of this pest) during the last year was an entomophthoralean fungus *Pandora neoaphidis* (Remaud. & Henneb.) Humber (= *Erynia neoaphidis* Remaud. & Henneb.). The ARS collection of entomopathogenic fungi (ARSEF) now accessioned several cultures of *Beauveria bassiana* (Balsamo) Vuillemin and *Verticillium lecanii* (Zimmermann) Viegas isolated from RWA in Idaho by M. Feng (Univ. of Idaho). While none of the fungal pathogens isolated from RWA in its endemic Eurasian sites have yet been received by the ARSEF collection, it does appear that this aphid host is very generally susceptible to nearly all of the fungi that are known from a wide range of aphid hosts.

Personnel

RWA Project	Personnel
RWA/Host Plant Interaction	Stillwater, OK Robert Burton, Research Entomologist John Burd, Biological Technician Brookings, SD Robert Kieckhefer, Research Entomologist Walter Riedell, Research Plant Physiologist
Host Plant Resistance	Stillwater, OK James Webster, Research Entomologist Keith Mirkes, Agricultural Research Technician Kathy Crump, Senior Agriculturalist
Germplasm Development	Stillwater, OK Cheryl Baker, Assistant Researcher (Cereal Breeding) Rita Veal, Biological Technician David Porter, Research Geneticist (Employment Date 12/4/89)
Alternate Hosts	Stillwater, OK Dean Kindler, Research Entomologist Tim Springer, Agricultural Research Technician
Insect Genetics	Stillwater, OK Gary Puterka, Research Entomologist Columbia, MO Bill Steiner, Research Geneticist, Insects
Simulation Modeling	Brookings, SD Norman Elliott, Research Biologist
Biosystematics	Beltsville, MD Manya Stoetzel, Research Entomologist Paul Marsh, Research Entomologist Mike Schauff, Research Entomologist

Biocontrol

Stillwater, OK
- David Reed, Research Entomologist
- Vacant, Insect Pathologist, Research Associate
- Brian Jones, Biological Technician

Behoust, France
- Ray Moore, Research Entomologist
- Tad Poprawski, Research Insect Pathologist
- Francis Gruber, Agricultural Assistant, Entomol.
- Guy Mercadier, Pathology Technician
- Eva Rey, Laboratory Technician

Brookings, SD
- Norman Elliott, Research Biologist
- Robert Kieckhefer, Research Entomologist

Newark, DE
- Roger Fuester, Research Entomologist
- Lawrence Ertle, Entomologist
- Paul Schaefer, Research Entomologist

Ithaca, NY
- Richard Humber, Microbiologist

Locations

Stillwater, Oklahoma

USDA-ARS Plant Science Research Laboratory
1301 North Western
Stillwater, OK 74075
Wheat and Other Cereal Crops Res. Unit
Robert Burton, Research Leader

Columbia, Missouri

USDA-ARS Biological Control of Insects Research Laboratory
Research Park, Route K
P.O. Box 7629
Columbia, MO 65205
Carlo Ignoffo, Research Leader

Brookings, South Dakota

USDA-ARS Northern Grain Insects Research Laboratory
Rural Route 3
Brookings, SD 57006
Crops and Entomology Research Unit
Jan Jackson, Research Leader

Beltsville, Maryland

USDA-ARS Systematic Entomology Laboratory
BARC-West, Bldg. 003
Beltsville, MD 20705
Douglass Miller, Research Leader

Behoust, France

USDA-ARS European Parasite Laboratory
Behoust, France
American Embassy - Agriculture
APO New York 09777
Raymond Moore, Research Leader

Newark, Delaware

USDA-ARS Beneficial Insects Research Laboratory
501 South Chapel Street
Newark, DE 19713
Beneficial Insects Introduction Research
Roger Fuester, Research Leader

Ithaca, New York

USDA-ARS Plant Protection Research
U.S. Nutrition Laboratory
Tower Road
Ithaca, NY 14853
Bill Brodie, Research Leader

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